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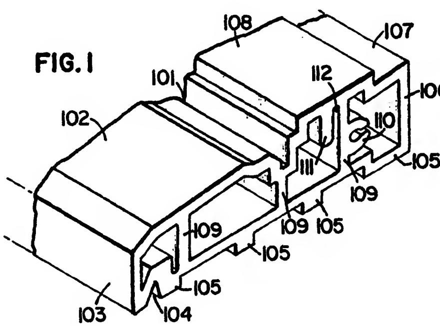
(54) **Polymer and wood fibre composite structural member.**

(57) A composite structural member, made of a polymer and wood fibre composite material, in the form of an extruded or injection moulded thermoplastic member in residential and commercial structures. The structural member can be used in a window or a door. The structural member has a hollow cross-section with at least one structural web (109) and at least one fastener web (110) formed within the member. The exterior of the extruded member is shaped and adapted for installation in a rough opening and to support window and door components. Such structural members can be assembled in a thermoplastic weld process. Welding is performed by heating and fusing the heated surfaces together to form a welded joint.

FIG. 1

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The invention relates to polymer/wood composite structural members, such as might be used in the fabrication of windows and doors for commercial and residential architecture.

Conventional window and door manufacture has commonly used vinyl, wood and metal members in forming structural members. Wood has been milled into shaped structural members that with glass can be assembled to form double hung or casement units, etc. and door assemblies. Wood windows, while structurally strong, useful and well adapted for use in many residential and commercial installations can have problems under certain circumstances related to the deterioration of the wood members. Wood windows also suffer from cost problems related to the availability of suitable wood for construction. Clear wood products are slowly becoming more scarce and are becoming more expensive as demand increases.

Metal, typically aluminum members, are also often combined with glass and formed into single unit sliding windows. Metal windows are typically suffer from the drawback that they tend to lose substantial quantities of heat from interior spaces.

Thermoplastic polyvinyl chloride has been combined with wood members in windows sold by Andersen Corporation for many years under the trade mark PERMASHIELD. The technology that has been used is disclosed in US-2926729 and US-3432883, and has been utilized in the manufacture of the plastic coatings or envelopes on wooden or other structural members. Generally, the cladding or coating technology used in making such windows involves extruded or injection moulding a thin polyvinyl chloride coating or envelope onto a shaped wooden structural member. Polyvinyl chloride thermoplastic polymer materials have been combined with wood and wood fibre to make extruded or injection moulded materials generally. However, the polyvinyl chloride materials of the prior art do not possess adequate properties to permit extrusion of structural members that are a direct replacement for wood. The polyvinyl chloride materials of the prior art do not have thermal and structural properties similar to wood members. The polymeric composites of the prior art fail to have sufficient compressive strength, modulus, coefficient of thermal expansion, coefficient of elasticity, workability or the ability to retain fasteners equivalent to or superior to wooden members. Further, many prior art extruded or injection moulded composites must be milled to form a final useful shape. One class of composite, a polyvinyl chloride and wood flour material, poses the added problem that wood dust, which can accumulate during manufacture, tends to be explosive at certain concentrations of wood flour in the air.

Accordingly, a substantial need exists for an improved structural member.

It has been found that the problems relating to forming a replacement for a wood structural member can be solved by forming structural members from a polymer and wood fibre composite material. The material can be made with an intentional recycle of by product streams comprising thermoplastic, adhesive, paint, preservatives, etc., common in window manufacture. The member can be produced by extrusion to form structural members of windows and doors, that have improved properties when compared to either metal or clad and unclad wooden members. For example, the member of the invention can be used in the form of rails, jambs, stiles, sills, tracks, stop and sash. The member of the invention can be heated and fused to form high strength welded joints in window and door assembly.

The composite can be extruded or injection moulded into a shape that is a direct substitute in terms of assembly properties and structural properties, for the equivalent milled shape in a wooden structural member. The structural member can be arranged to have a coefficient of thermal expansion that approximates that of wood, a low heat transmission rate, an improved resistance to insect attack and rot while in use compared with that of wood, and a hardness and rigidity that permits sawing, milling and fastening retention comparable to wood members. Furthermore, production of the member of the invention gives rise to lower production of waste materials than the production of members from wood and plastic materials alone, and can indeed use waste materials from other production techniques.

The member of the invention will generally have a cross-sectional shape that can be adapted to window or door construction, and the installation of useful window or door members or parts into the structural member. The structural member can be an extrusion in the form or shape of rail, jamb, stile, sill, track, stop or sash. Additionally, non-structural trim elements such as grid, cove, quarter-round, etc., can be made. The extruded or injection moulded structural member can have a hollow cross-section with a rigid exterior shell or wall. The member can include at least one internal structural or support web and at least one internal structural fastener anchor. The member can be straight. The shell, web and anchor in cooperation have sufficient strength to permit the structural member to withstand normal wear and tear related to the operation of the window or door. Fasteners can be used to assemble the window or door unit. The fasteners must remain secure during window life to survive as a structural member or member of the residential or commercial architecture. It has been found further that the structural members of the invention can be joined by fusing mating surfaces formed in the structural m mber at elevated temp rature to form a w lded joint having superior strength and rigidity when compared to prior art wooden members.

These structural members are made from a polyvinyl chloride and wood fibre composite. The composite

can be made with an intentional recycle of by product streams comprising thermoplastic, adhesive, paint, preservatives, etc., common in window manufacture. More particularly, the invention relates to improved materials adapted for extrusion into the structural members of windows and doors that have improved properties when compared to either metal or to clad and unclad wooden members. The structural members of the invention can be used in the form of rails, jambs, stiles, sills, tracks, stop and sash. The structural members of the invention can be heated and fused to form high strength welded joints in window and door assembly.Vinyl materials have been used in forming envelopes, trim and seal members in window units. Such vinyl materials typically comprise a major proportion of a vinyl polymer with inorganic pigment, fillers, lubricants, etc. Extruded or injection moulded thermoplastic materials have been used in window and door manufacture. Filled and unfilled flexible and rigid thermoplastic materials have been extruded or injection moulded into useful seals, trim members, fasteners, and other wood window construction parts.

The polyvinyl chloride used in the composite material can be polyvinyl chloride homopolymer free of additional ingredients or it can be polyvinyl chloride homopolymer, copolymer, etc., polyvinyl chloride alloy or any of the polymeric materials compounded with additional additives. The sawdust can be virgin sawdust or can comprise sawdust recycle from the wood manufacturing process. Typically, the composition comprises from at least about 30%, preferably at least about 35%, especially more than about 50% of the polyvinyl chloride material. The composition will comprise less than 70%, preferably less than about 65% of the polyvinyl chloride material. The composition will generally comprise at least about 30%, preferably at least about 35%, of the wood fibre material. The composition will generally comprise less than 55%, preferably less than 50%, of the wood fibre material. It can be preferred to use a composition which comprises approximately 60 wt % polyvinyl chloride with 40 wt % sawdust.

The extruded or injection moulded member can a linear member with a hollow profile.

The profile comprises an exterior wall or shell substantially enclosing a hollow interior. The interior can contain at least one structural web providing support for the walls and can contain at least one fastener anchor web to ensure that the composite member can be attached to other members using commonly available fasteners which are strongly retained by the fastener anchor web.

The structural member is typically shaped by the extrusion or injection moulding process such that the member can replace a structural or trim member of existing window or door manufacture. Such structural members can take a variety of shapes which surface contours are adapted to the window or door assembly process and are adapted to the operation of working parts of the window or door. Such structural members can contain screen insert supports, sliding window or sliding door supports, cut-outs for hardware installation, anchor locations, etc. The thermoplastic composite material typically forms a shell or wall exterior substantially surrounding the interior space. The exterior shell or wall contains a surface shaped as needed to assemble the window and surfaces needed for cooperation with the other working parts of the window and the rough opening as described above.

The interior of the structural member is commonly provided with one or more structural webs which in a direction of applied stress supports the structure. Structural web typically comprises a wall, post, support member, or other formed structural element which increases compressive strength, torsion strength, or other structural or mechanical property. Such structural web connects the adjacent or opposing surfaces of the interior of the structural member. More than one structural web can be placed to carry stress from surface to surface at the locations of the application of stress to protect the structural member from crushing, torsional failure or general breakage. Typically, such support webs are extruded or injection moulded during the manufacture of the structural material. However, a support can be post added from parts made during separate manufacturing operations.

The internal space of the structural member can also contain a fastener anchor or fastener installation support. Such an anchor or support means provides a locus for the introduction of a screw, nail, bolt or other fastener used in either assembling the unit or anchoring the unit to a rough opening in the commercial or residential structure. The anchor web typically is conformed to adapt itself to the geometry of the anchor and can simply comprise an angular opening in a formed composite structure, can comprise opposing surfaces having a gap or valley approximately equal to the screw thickness, can be geometrically formed to match a key or other lock mechanism, or can take the form of any commonly available automatic fastener means available to the window manufacturer from fastener or anchor parts manufactured by companies such as Amerock Corp., Illinois Tool Works and others.

The structural member of the invention can have premoulded paths or paths machined into th moulded thermoplastic composite for passage of door or window units, fasteners such as screws, nails, tc. Such paths can be counter sunk, metal lined, or otherwise adapted to the geometry or the composition of the fastener materials. The structural member can have mating surfaces premoulded in order to provide rapid assembly with other window members of similar or different compositions having similarly adapted mating surfaces. Fur-

ther, the structural member can have mating surfaces formed in the shell of the structural member adapted to moveable window sash or door sash or other moveable parts used in window operations.

The structural member of the invention can have a mating surface adapted for the attachment of the weigh subfloor or base, framing studs or side moulding or beam, top portion of the structural member to the rough opening. Such a mating surface can be flat or can have a geometry designed to permit easy installation, sufficient support and attachment to the rough opening. The structural member shell can have other surfaces adapted to an exterior trim and interior mating with wood trim pieces and other surfaces formed into the exposed sides of the structural member adapted to the installation of metal runners, wood trim parts, door runner supports, or other metal, plastic, or wood members commonly used in the assembly of windows and doors.

Different members of the structural members of windows and doors have different physical requirements for a stable installation. The minimum compressive strength for a weight bearing sill member must be at least 680 kg (1500 lbs), preferably 900 kg (2000 lbs). The compressive strength is typically measured in the direction that load is normally placed on the member. The direction can be a normal force or a force directed along the axis of the unit when installed in the side frame or base a window or door. The Young's modulus of a vertical jamb or stile in a window or door should be at least 3440 MPa (500,000 psi), preferably 5520 MPa (800,000 psi) and most preferably 6900 MPa ($10^6$ psi). We have found that the coefficient of thermal expansion of the polymer and wood fibre composite material is a reasonable compromise between the longitudinal coefficient of thermal expansion of PVC which is typically about $7.2 \times 10^{-5}$ °C$^{-1}$ ($4 \times 10^{-5}$ in./in.°F) and the thermal expansion of wood in the transverse direction which is approximately $0.36 \times 10^{-5}$ °C$^{-1}$ ($0.2 \times 10^{-5}$ in./in.°F). Depending upon the proportions of materials and the degree to which the materials are blended and uniform, the coefficient thermal expansion of the material can range from about 2.7 to $5.4 \times 10^{-5}$ °C$^{-1}$ (1.5 to $3.0 \times 10^{-5}$ in./in.°F), preferably about 2.9 to $3.2 \times 10^{-5}$ °C$^{-1}$ (1.6 to $1.8 \times 10^{-5}$ in./in.°F).

The structural member of the invention can be assembled with a variety of known mechanical fastener techniques. Such techniques include screws, nails, and other hardware. The structural members of the invention can also be joined by an insert into the hollow profile, glue, or a melt fusing technique wherein a fused weld is formed at a joint between two structural members. The structural members can be cut or milled to form conventional mating surfaces including 90° angle joints, rabbit joints, tongue and groove joints, butt joints, etc. Such joints can be bonded using an insert placed into the hollow profile that is hidden when joinery is compl te. Such an insert can be glued or thermally welded into place. The insert can be injection moulded or formed from similar thermoplastics and can have a service adapted for compression fitting and secure attachment to the structural member of the invention. Such an insert can project from approximately 1 to 5 inches into the hollow interior of the structural member. The insert can be shaped to form a 90° angle, a 180° extension, or other acute or obtuse angle required in the assembly of the structural member. Further, such members can be manufactured by milling the mating faces and gluing members together with a solvent, structural or hot melt adhesive. Solvent borne adhesives that can act to dissolve or soften thermoplastic present in the structural member and to promote solvent based adhesion or welding of the materials are known in polyvinyl chloride technology. In the welding technique, once the joint surfaces are formed, the surfaces of the joint can be heated to a temperature above the melting point of the composite material and while hot, the mating surfaces can be contacted in a configuration required in this assembled structure. The contacted heated surfaces fuse through an intimate mixing of molten thermoplastic from each surface. Once mixed, the materials cool to form a structural joint having strength typically greater than joinery made with conventional techniques. Any excess thermoplastic melt that is forced from the joint area by pressure in assembling the surfaces can be removed using a heated surface, mechanical routing or a precision knife cutter.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a perspective view from above showing the an extruded or injection moulded sill unit used in the base assembly of a sliding glass door having a stationary and moveable glass units. The sill contains an exterior shell or wall and interior structural webs with a fastener anchor web. These elements cooperate to provide superior strength, workability and fastener retention when compared to similarly sized wood members.

FIGURE 2 is a perspective view from below showing the sill unit.

FIGURE 3 is a perspective view from the side of a welded joint between two structural units. Two extruded composite structural members are joined at a 90° angle using a welded or fused joint between the members.

FIGURE 4 is an elevation of a different embodiment of the sill member of the invention having a fastener anchor web of an alternative design.

Referring to the drawings, Fig. 1 shows a sill which is adapt d for installation into the base or support for the door frame. Hing d glass doors (not shown) are stopped on an aluminum sill (not shown) having grooved runners supporting the glass door panel. The aluminum sill can be snap-fit onto the extruded sill by installation onto the extruded sill at a snap-fit attachment groove 101. The aluminum piec cov rs the sill from th groove

101 over the snap-fit land 102, the exterior face 103 ending in the snap-fit groove 104 for a mechanically secure attachment. The sill rests on the subfloor supported by the sill rests 105. The interior installation face 106 abuts subflooring or trim additional members of the assembled sliding door unit. After the sliding door is installed an oak threshold is installed onto the oak threshold lands 107 and 108. The oak threshold has faces milled to match the threshold land areas. The interior of the sill shows vertical support webs 109. The support webs 109 provide compression strength supporting the top of the sill, the snap-fit lands 102 and the oak threshold lands 107 and 108. The sill also includes a C-shaped fastener anchor 110 which is moulded integrally with the support web 109. The typical fastener such as a screw can pass into the anchor space in the anchor 110. An additional attachment web 111 is coextruded with the oak threshold land 109 providing an attachment anchor valley 112 for screws passing vertically through the oak threshold land 108 into the valley screw anchor 112.

Fig. 2 shows a perspective view from below of an extruded sill member as shown in Fig. 1. The snap-fit attachment groove 101 for the aluminum sill, the snap-fit land 102 and the exterior face 103 is shown. The snap-fit groove 104 is shown on the bottom view. The sill rest members 105 are shown in the bottom view of the sill. The interior installation face 106 is hidden from sight. The oak threshold lands 107 and 108 are also hidden from view. The vertical support webs 109 are shown providing support for the oak threshold lands 107 and 108 and the snap-fit land 102. The fastener anchor 110 the vertical anchor web 111 and the fastener anchor valley 112 are also shown in the figure.

Fig. 3 is a perspective view from the side of a welded corner of a joint between two structural members that can be the exterior framing portion of a window or door unit. The top portion 301 and the wall portion 302 can be installed into a rough framed opening (not shown). The interior top surface 303 and 304 can have, installed plastic, wood or metal members for window or door operation. Such members can be sealed, weather stripped or similarly fixed in place. The structural integrity of the unit is obtained by welding the units at the weld line 305 which comprises a fused area that extends from the interior face 306 through the exterior face 307. The weld is finished using a heated tool mechanical routing or precision knife to create a surface 308 that forms an attractive finished look by heating the joined area on the exterior corner of the fused zone. Any irregularity caused by the expulsion of melted material from the fused zone is smoothed by forming the surface 308.

It has been found that joining a structural members can be accomplished using a melt fuse process. In the production of the joint shown in Fig. 3, the extruded member is first mitred to form a 45° cut. The mitred surface is then contacted with a heated member for sufficient period to melt the mitred joint to a depth of about 2 mm. The melt reaches a temperature greater than about melting point of the thermoplastic (i.e.,) about 225°C or more. A similar procedure is performed on the mating mitred surface. The melt mitred surfaces are joined in a fixed 90° angle position pressure is placed on the members until the melt mitred surfaces form a fused joint. The materials are held in place until the fused joint cools, solidifies and becomes mechanically sound. The formed joint is then removed from any mechanical restraints.

Figure 4 is an elevation of the structural member of the invention with an alternative fastener anchor. Th member is identical to the member of figure 2 except in the fastener anchor. In Figure 4, a first anchor surface 401 and a second anchor surface 402 is used. These surfaces are included in webs 403 and 404 which act as support webs.

The structural member of the invention can be manufactured using any typical thermoplastic forming operation. Preferred forming processes include extrusion and injection moulding.

Pellet

The polyvinyl chloride and wood fibre can be combined and formed into a pellet using a thermoplastic extrusion process. A linear extrudate is similar to a pellet except the extrudate is not left in a linear format and is cut into discrete pellet units. Wood fibre can be introduced into a pellet making process in a number of sizes. We believe that the wood fibre should have a minimum size of length and width of at least 1 mm because smaller particles produce reduced physical properties in the member and because wood flour tends to be explosive at certain wood to air ratios. Further, wood fibre of appropriate size and an aspect ratio greater than 1 tends to increase the physical properties of the extruded structural member. However, useful structural members can be made with a fibre of very large size. Fibres that are up to 3 cm in length and 0.5 cm in thickness can be used as input to the pellet or linear extrudate manufacturing process. However, particles of this size do not produce highest surface quality structural members or maximized strength. The best appearing product with maximized structural properties are manufactured within a range of particle size as set forth below. Further, large particle wood fibre can be reduced in size by grinding or other similar process s that produce a fibre similar to sawdust having the stated dimensions and aspect ratio. On further advantage of manufacturing sawdust of the desired size is that the fibre material can be pre-dried before introduction into the pellet or linear

extrudate manufacturing process.

The polyvinyl chloride and wood fibre are intimately contacted to form the composite material at high temperatures and pressures to insure that the wood fibre and polymeric material are wetted, mixed and extruded in a form such that the polymer material, on a microscopic basis, coats and flows into the pores, cavities, etc., of the fibres.

The fibres are preferably oriented by the extrusion process in the extrusion direction. Such orientation causes overlapping of adjacent parallel fibres and polymeric coating of the oriented fibres resulting a material useful for manufacture of improved structural members with improved physical properties. The structural members have substantially increased strength and tensile modulus with a coefficient of thermal expansion and a modulus of elasticity that is optimized for window and doors. The properties are a useful compromise between wood, aluminum and neat polymer.

Moisture control is an important element of manufacturing a useful linear extrudate or pellet. Depending on the equipment used and processing conditions, control in the water content of the linear extrudate or pellet can be important in forming a successful structural member substantially free of internal voids or surface blemishes. Water present in the sawdust during the formation of pellet or linear extrudate when heated can flash from the surface of the newly extruded structural member and can come as a result of a rapid volatilization, form a steam bubble deep in the interior of the extruded member which can pass from the interior through the hot thermoplastic extrudate leaving a substantial flaw. In a similar fashion, surface water can bubble and l ave cracks, bubbles or other surface flaws in the extruded member.

Trees when cut, depending on relative humidity and season, can contain from 30 to 300 wt % water bas d on fibre content. After rough cutting and finishing into sized lumber, seasoned wood can have a water content of from 20 to 30 wt % based on fibre content. Kiln dried sized lumber cut to length can have a water content typically in the range of 8 to 12%, commonly 8 to 10 wt % based on fibre. Some wood source, such as poplar or aspen, can have increased moisture content while some hard woods can have reduced water content.

Because of the variation in water content of wood fibre source and the sensitivity of extrudate to water content control of water to a level of less than 8 wt % in the pellet based on pellet weight is important. Structural members extruded in non-vented extrusion process, the pellet should be as dry as possible and have a water content between 0.01 and 5%, preferably about 0.1 to 3.5 wt %. When using vented equipment in manufacturing the extruded linear member, a water content of less than 8 wt % can be tolerated if processing conditions are such that vented extrusion equipment can dry the thermoplastic material prior to the final formation of the structural member at the extrusion head.

The pellets or linear extrudate of the invention are made by extrusion of the polyvinyl chloride and wood fibre composite through an extrusion die resulting in a linear extrudate that can be cut into a pellet shape. The pellet cross-section can be any arbitrary shape depending on the extrusion die geometry. However, we hav found that a regular geometric cross-sectional shape can be useful. Such regular cross-sectional shapes include a triangle, a square, a rectangle, a hexagonal, an oval, a circle, etc. The preferred shape of the pellet is a regular cylinder having a roughly circular or somewhat oval cross-section. The pellet volume is preferably greater than about 12 $mm^3$. The preferred pellet is a right circular cylinder, the preferred radius of the cylinder is at least 1.5 mm with a length of at least 1 mm. Preferably, the pellet has a radius of 1 to 5 mm and a length of 1 to 10 mm. Most preferably, the cylinder has a radius of 2.3 to 2.6 mm, a length of 2.4 to 4.7 mm, a volume of 40 to 100 $mm^3$, a weight of 40 to 130 mg and a bulk density of about 0.2 to 0.8 $g.mm^{-3}$. The linear extrudate is similar to the pellet in dimensions except the length is indeterminate.

We have found that the interaction, on a microscopic level, between the polymer mass and the wood fibre is an important element of the invention. We have found that the physical properties of an extruded member are improved when the polymer melt during extrusion of the pellet or linear member thoroughly wets and penetrates the wood fibre particles. The thermoplastic material comprises an exterior continuous organic polymer phase with the wood particle dispersed as a discontinuous phase in the continuous polymer phase. The material during mixing and extrusion produces an aspect ratio of at least 1.1 and preferably between 2 and 4, optimizes orientation such as at least 20%, preferably 40% of the fibres are oriented, above random orientation of 40-50%, in an extruder direction and are thoroughly mixed and wetted by the polymer such that all exterior surfaces of the wood fibre are in contact with the polymer material. This means, that any pore, crevice, crack, passage way, indentation, etc., is fully filled by thermoplastic material. Such penetration as attained by ensuring that the viscosity of the polymer melt is reduced by operations at elevated temperature and the use of sufficient pressure to force the polymer into the available internal pores, cracks and crevices in and on the surface of the wood fibre.

During the pellet or linear extrudate manufacture, substantial work is done in providing a uniform disp rsion of the wood into the polymer material. Such work produces substantial orientation which when extruded into a final structural member, permits the orientation of the fibres in the structural member to be increased in th

extruder direction resulting in improved structural properties in the sense of compression strength in response to a normal force or in a torsion or flexing mode.

The pellet dimensions are selected for both convenience in manufacturing and in optimizing the final properties of the extruded materials. A pellet that is with dimensions substantially less than the dimensions set forth above are difficult to extrude, pelletize and handle in storage. Pellets larger than the range recited are difficult to cool, introduce into extrusion equipment, melt and extrude into a finished structural member.

PVC Homopolymer, copolymers and polymeric alloys

Polyvinyl chloride is a common commodity thermoplastic polymer. Vinyl chloride monomer is made from a variety of different processes such as the reaction of acetylene and hydrogen chloride and the direct chlorination of ethylene. Polyvinyl chloride is typically manufactured by the free radical polymerization of vinyl chloride resulting in a useful thermoplastic polymer. After polymerization, polyvinyl chloride is commonly combined with thermal stabilizers, lubricants, plasticizers, organic and inorganic pigments, fillers, biocides, processing aids, flame retardants and other commonly available additive materials. Polyvinyl chloride can also be combined with other vinyl monomers in the manufacture of polyvinyl chloride copolymers. Such copolymers can be linear copolymers, branched copolymers, graft copolymers, random copolymers, regular repeating copolymers, block copolymers, etc. Monomers that can be combined with vinyl chloride to form vinyl chloride copolymers include a acrylonitrile, alpha-olefins such as ethylene, propylene, etc., chlorinated monomers such as vinylidene dichloride, acrylate monomers such as acrylic acid, methylacrylate, methylmethacrylate, acrylamide, hydroxyethyl acrylate, and others, styrenic monomers such as styrene, alphamethyl styrene, vinyl toluene, etc.; vinyl acetate; and other commonly available ethylenically unsaturated monomer compositions. Such monomers can be used in an amount of up to about 50 mol %, the balance being vinyl chloride. Polymer blends or polymer alloys can be useful in manufacturing the pellet or linear extrudate of the invention. Such alloys typically comprise two miscible polymers blended to form a uniform composition. Scientific and commercial progress in the area of polymer blends has lead to the realization that important physical property improvements can be made not by developing new polymer material but by forming miscible polymer blends or alloys. A polymer alloy at equilibrium comprises a mixture of two amorphous polymers existing as a single phase of inability mixed segments of the two macro molecular members. Miscible amorphous polymers form glasses upon sufficient cooling and a homogeneous or miscible polymer blend exhibits a single, composition dependent glass transition temperature ($T_g$), or as an immiscible or non-alloyed blend of polymers typically displays two or more glass transition temperatures associated with immiscible polymer phase. In the simplest cases, the properties of polymer alloys reflect a composition weighted average of properties possessed by the members. In general, however, the property dependence on composition varies in a complex way with a particular property, the nature of the members (glassy, rubbery or semi-crystalline), the thermodynamic state of the blend, and its mechanical state whether molecules and phases are oriented. Polyvinyl chloride forms a number of known polymer alloys including, for example, polyvinyl chloride/nitrile rubber; polyvinyl chloride and related chlorinated copolymers and terpolymers of polyvinyl chloride or vinylidine dichloride; polyvinyl chloride/alphamethyl styrene-acrylonitrile copolymer blends; polyvinyl chloride/polyethylene; polyvinyl chloride/chlorinated polyethylene and others.

The primary requirement for the substantially thermoplastic polymeric material is that it retain sufficient thermoplastic properties to permit melt blending with wood fibre, permit formation of linear extrudate pellets, and to permit the composition material or pellet to be extruded in a thermoplastic process forming the rigid structural member. Polyvinyl chloride homopolymers copolymers and polymer alloys are available from a number of manufacturers including B.F. Goodrich, Vista, Air Products, Occidental Chemicals, etc. Preferred polyvinyl chloride materials are polyvinyl chloride homopolymer having a molecular weight of about 90,000 ± 50,000, most preferably about 88,000 ± 10,000.

Wood fibre

Wood fibre, in terms of abundance and suitability can be derived from either soft woods or evergreens or from hard woods commonly known as broad leaf deciduous trees. Soft woods are generally preferred for fibre manufacture because the resulting fibres are longer, contain high percentages of lignin and lower percentages of hemicellulose than hard woods. While soft wood is the primary source of fibre for the invention, additional fibre make-up can be derived from a number of secondary or fibre reclaim sources including bamboo, rice, sugar cane, and recycled fibres from newspap rs, boxes, computer printouts, etc.

However, the primary sourc for wood fibre of this inv ntion comprises the wood fibre by-product of sawing or milling soft woods commonly known as sawdust or milling tailings. Such wood fibre has a regular reproducible shape and aspect ratio. Th fibr s based on a random selection of about 100 fibres are commonly at least

1 mm in length, 3 mm in thickness and commonly have an aspect ratio of at least 1.8. Preferably, the fibres are 1 to 10 mm in length, 0.3 to 1.5 mm in thickness with an aspect ratio between 2 and 7, preferably 2.5 to 6.0. The preferred fibre for use in this invention are fibres derived from processes common in the manufacture of windows and doors. Wooden members are commonly ripped or sawed to size in a cross grain direction to form appropriate lengths and widths of wood materials. The by-product of such sawing operations is a substantial quantity of sawdust. In shaping a regular shaped piece of wood into a useful milled shape, wood is commonly passed through machines which selectively removes wood from the piece leaving the useful shape. Such milling operations produces substantial quantities of sawdust or mill tailing by-products. Lastly, when shaped materials are cut to size and mitred joints, butt joints, overlapping joints, mortise and tenon joints are manufactured from pre-shaped wooden members, substantial trim is produced. Such large trim pieces are commonly cut and machined to convert the larger objects into wood fibre having dimensions approximating sawdust or mill tilling dimensions. These materials can be dry blended to form input to the pelletizing function. Further, the streams can be pre-mitred to the preferred particle size of sawdust or can be post-milled.

Such sawdust material can contain substantial proportions of a by-product stream. Such by-products include polyvinyl chloride or other polymer materials that have been used as coating, cladding or envelope on wooden members; recycled structural members made from thermoplastic materials such as polyethylene, polypropylene, polystyrene, polyethylene terephthalate, etc.; polymeric materials from coatings; adhesive members in the form of hot melt adhesives, solvent based adhesives, powdered adhesives, etc.; paints including water based paints, alkyd paints, epoxy paints, etc.; preservatives, anti-fungal agents, anti-bacterial agents, insecticides, etc., and other streams common in the manufacture of wooden doors and windows. The total by-product stream content of the wood fibre materials is commonly less than 25 wt % of the total wood fibre input into the polyvinyl chloride wood fibre product. Of the total recycle, approximately 10 wt % of that can compris a vinyl polymer commonly polyvinyl chloride. Commonly, the intentional recycle ranges from about 1 to about 25 wt %, preferably about 2 to about 20 wt %, most commonly from about 3 to about 15 wt % of contaminants based on the sawdust.

Moisture control

Food fibre, sawdust, has a substantial proportion of water associated with the fibre. Water naturally is incorporated in the growth cycle of living wood. Such water remains in the wood even after substantial drying cycles in lumber manufacture. In seasoned finished lumber used in the manufacture of wooden structural members, the sawdust derived from such operations can contain about 20% water or less. We have found that control of the water common in wood fibres used in the polyvinyl chloride/wood fibre composite materials and pellet products of the invention is a critical aspect to obtaining consistent high quality surface finish and dimensional stability of the PVC/wood fibre composite structural members. During the manufacture of the pellet material, we have found that the removal of substantial proportion of the water is required to obtain a pellet optimized for further processing into the structural members. The maximum water content of the polyvinyl chloride/wood fibre composition or pellet is 10 wt % or less, preferably 8.0 wt % or less and most preferably the composition or pellet material contains from about 0.01 to 3.5 wt % water. Preferably, the water is removed after the material is mixed and formed into an extrusion prior to cutting into pellets. At this stage, water can be removed using the elevated temperature of the material at atmospheric pressure or at reduced pressure to facilitate water removal. The production can be optimized to result in substantial control and uniformity of water in the pellet product.

Composition and pellet manufacture

In the manufacture of the composition and pellet of the invention, the manufacture and procedure requires two important steps. A first blending step and a second pelletizing step.

During the blending step, the polymer and wood fibre are intimately mixed by high shear mixing members with recycled material to form a polymer wood composite wherein the polymer mixture comprises a continuous organic phase and the wood fibre with the recycled materials forms a discontinuous phase suspended or dispersed throughout the polymer phase. The manufacture of the dispersed fibre phase within a continuous polymer phase requires substantial mechanical input. Such input can be achieved using a variety of mixing means including preferably extruder mechanisms wherein the materials are mixed under conditions of high shear until the appropriate degree of wetting and intimate contact is achiev d. Aft r the materials are fully mixed, the moisture content must be controlled at a moisture removal station. The heated composit is exposed to atmospheric pressure or reduced pressure at elevated temp rature for a sufficient period of time to remov moisture resulting in a final moisture content of about 8 wt % or l ss. Lastly, th polymer fibre is aligned and extruded

into a useful form.

The preferred equipment for mixing and extruding the composition and wood pellet of the invention is an industrial extruder device. Such extruders can be obtained from a variety of manufacturers including Cincinnati Millicron, etc.

The materials feed to the extruder can comprise from about 30 to 50 wt % of sawdust including recycled impurity along with from about 50 to 70 wt % of polyvinyl chloride polymer compositions. Preferably, about 35 to 45 wt % wood fibre or sawdust is combined with 65 to 55 wt % polyvinyl chloride homopolymer. The polyvinyl chloride feed is commonly in a small particulate size which can take the form of flake, pellet, powder, etc. Any polymer form can be used such that the polymer can be dry mixed with the sawdust to result in a substantially uniform pre-mix. The wood fibre or sawdust input can be derived from a number of plant locations including the sawdust resulting from rip or cross grain sawing, milling of wood products or the intentional commuting or fibre manufacture from wood scrap. Such materials can be used directly from the operations resulting in the wood fibre by-product or the by-products can be blended to form a blended product. Further, any wood fibre material alone, or in combination with other wood fibre materials, can be blended with a by-product stream from the manufacturer of wood windows as discussed above. The wood fibre or sawdust can be combined with other fibres and recycled in commonly available particulate handling equipment.

Polymer and wood fibre are then dry blended in appropriate proportions prior to introduction into blending equipment. Such blending steps can occur in separate powder handling equipment or the polymer fibre streams can be simultaneously introduced into the mixing station at appropriate feed ratios to ensure appropriate product composition.

In a preferred mode, the wood fibre is placed in a hopper, controlled by weight or by volume, to meter the sawdust at a desired volume while the polymer is introduced into a similar hopper have a volumetric metering input system. The volumes are adjusted to ensure that the composite material contains appropriate proportions on a weight basis of polymer and wood fibre. The fibres are introduced into a twin screw extrusion device. The extrusion device has a mixing section, a transport section and an extruder section. Each section has a desired heat profile resulting in a useful product. The materials are introduced into the extruder at a rate of about 600 to about 1000 pounds of material per hour and are initially heated to a temperature of about 215 to 225°C. In the intake section, the stage is maintained at about 215°C to 225°C. In the mixing section, the temperature of the twin screw mixing stage is staged beginning at a temperature of about 205 to 215°C leading to a final temperature in the melt section of about 195 to 205°C at spaced stages. One the material leaves the blending stage, it is introduced into a three stage extruder with a temperature in the initial section of 185 to 195°C wherein the mixed thermoplastic stream is divided into a number of cylindrical streams through a head section and extruded in a final zone of 195 to 200°C. Such head sections can contain a circular distribution of 10 to 500, preferably 20 to 250 orifices having a cross-sectional shape leading to the production of a regular cylindrical pellet. As the material is extruded from the head it is cut with a knife at a rotational speed of about 100 to 400 rpm resulting in the desired pellet length.

The composite thermoplastic material is then extruded or injection moulded into the structural members of the invention. Preferably, the composite composition is in the form of a pellet or linear extrudate which is directed into the extrusion or injection moulding apparatus. In extruder operations, the pellet materials of the invention are introduced into an extruder and extruded into the structural member of the invention. The extruder can be any conventional extruder equipment including Moldavia, Cincinnati Millicron Extruders, etc. Preferably, parallel twin screw extruders having an appropriate shaped four zone barrel are used. The extrudate product is typically extruded into a cooling water tank at a rate of about 4 feet of structural member per minute. A vacuum gauged device can be used to maintain accurate dimensions in the extrudate. The melt temperature in the extruder can be between 200 and 215°C (390 and 420°F). The melt in the extruder is commonly vented to remove water and the vent is operated at vacuum of not less than 3 inches of mercury. The extruder barrel has zones of temperature that decrease from a maximum of about 240°C to a minimum of between 180 and 190°C and four successive heating zones or steps.

Similarly, the structural members of the invention can be manufactured by injection moulding. Injection moulding processes inject thermoplastic materials at above the melt point under pressure into moulds having a shape desired for the final moulded products. The machines can be either reciprocating or two stage screw driven. Other machines that can be used are plunger mechanisms. Injection moulding produces parts in large volume with close tolerances. Parts can be moulded in combination of thermoplastic materials with glass, asbestos, taal carbon, metals and non-metals, etc. In injection moulding, material is fed from a hopper into a feed shoot into the mechanism used in the individual injection moulding apparatus to melt and place the melt injection mat rial under pressure. The mechanism then uses a reciprocating screw, plung r or other injection means to force the melt under pressure into the mould. The pr ssure forces the material to take a shape substantially identical to that of the mould interior.

Experimental

Using the methods for manufacturing a pellet and extruding the pellet into a structural member, an extruded piece as shown in Figs. 1 and 2 of the application were manufactured. The overall width of the unit was about 8 cm (3.165 in) and the height was about 2.7 cm (1.062 in). The wall thickness of any of the elements of the extrudate was about 0.3 cm (0.120 in). A Cincinnati Millicron extruder with an HP barrel, a Cincinnati pelletizer screws, and AEG K-20 pelletizing head with 260 holes, each hole having a diameter of about 0.05 cm (0.02 in) was used to make a pellet. The input to the pelletizer comprise approximately 60 wt % polymer and 40 wt % sawdust. The polymer material comprises a thermoplastic mixture of approximately 100 parts of vinyl chloride homopolymer, about 15 parts titanium dioxide, about 2 parts ethylene-bis-stearimide wax lubricant, about 1.5 parts calcium stearate, about 7.5 parts Rohm &Haas 980-T acrylic resin impact modifier/process aid and about 2 parts of dimethyl tin thioglycolate. The sawdust input comprises a wood fibre particle containing about 5 wt % recycled polyvinyl chloride having a composition substantially identical to the polyvinyl chloride recited above. The initial melt temperature of the extruder was maintained between 375°C and 425°C. The pelletizer was operated on a vinyl/sawdust combined ratio through put of about 800 pounds/hour. In the initial extruder feed zone, the barrel temperature was maintained between 215 and 225°C. In the intake zone, the barrel was maintained at 215 and 225°C, and the compression zone was maintained at between 205 and 215°C and in the melt zone the temperature was maintained at 195 to 205°C. The die was divided into three zones, the first zone at 185 to 195°C, the second zone at 185 to 195°C and in the final die zone 195 at 205°C. The pelletizing head was operated at a setting providing 100 to 300 rpm resulting in a pellet with a diameter of about 5 mm and a length as shown in the following Table.

In a similar fashion, the sill of Figs. 1 and 2 was extruded from a vinyl wood composite pellet using an extruder within an appropriate extruder die. The melt temperature of the input to the machine was between 390 and 420°F. A vacuum was pulled on the melt mass of no less than 7.6 cm (3 in) mercury. The melt temperatures through the extruder was maintained at the following temperature settings:

| | |
|---|---|
| Barrel Zone No. 1 | - 220-230°C |
| Barrel Zone No. 2 | - 220-230°C |
| Barrel Zone No. 3 | - 215-225°C |
| Barrel Zone No. 4 | - 200-210°C |
| Barrel Zone No. 5 | - 185-195°C |
| Die Zone No. 6 | - 175-185°C |
| Die Zone No. 7 | - 175-185°C |
| Die Zone No. 8 | - 175-185°C |

The screw heater oil stream was maintained at 180 to 190°C. The material was extruded at a line speed maintained between 1.52 and 2.13 m.min$^{-1}$ (5 and 7 ft./min).

Lengths of the sill, shown in Figs. 1 and 2, were manufactured and tested for compression load, cross grain screw retention, longitudinal screw retention, thermal transmittance, and cleave strength of welded 90° mitred joints. The following Tables display the test data developed in these experiments.

Compression and screw retention

PRODUCTS TESTED

Reclaimed Composite material (40% sawdust, pine, 60% PVC) extruded into Fig. 1 shape.

PURPOSE OF TEST

Det rmine maximum compression load, cross-grain screw retention and longitudinal screw retention.

| | COMPRESSION LOAD Fig 1 (kg) | COMPRESSION RETENTION Fig 2 (kg) | COMPRESSION RETENTION Fig 3 (kg) |
|---|---|---|---|
| Sill of Fig 1 | 1048 | 185 | 309 |
| Pine | 899 | 39 | 278 |

METHOD OF TESTING

Materials were extruded to the sill in Fig. 1.

Compression preparation and testing was done according to ASTM D143 sec. 79. The 22480.0 lb. load cell was used with a testing rate of 0.012 in/min to a maximum displacement of 0.1 in.

Screw retention preparation and testing was done according to ASTM D1761. The 2248.0 lb load cell was used with a testing rate of 0.01 in/min.

Thermal Properties

PURPOSE OF TEST

Evaluate the thermal transmittance of the sill member of Fig. 1, relative to the standard pine material, by monitoring interior subsill surface temperatures when the door exterior is exposed to cold temperature.

METHOD OF TESTING

The reclaimed composite sill was extruded to the profile indicated in Fig. 1. The material consists of a 40/60 wt % sawdust/PVC mixture.

A 118 cm (46.5 in) length of the reclaimed composite sill was used to replace one-half of the standard pine sill installed in the opening of the wind tunnel cold box. Installation flanges were fastened to the rough opening with duct tape. Fibreglass insulation was installed around the head and side jambs. Silicone sealant was applied beneath the sill and 1.9 cm (0.75 in) lumber was used as an interior trim at the head and side jambs.

CONCLUSION

The interior surface of the composite sill is about 1.1°C (2°F) colder than a pine sill (see Fig. 2) when the exterior temperatures is -23°C (-10°F) and a normal room temperature is maintained.

Neither pine nor the composite sill exhibited condensation at an interior relative humidity of about 25%.

Weld Cleave Strength

| PART DESCRIPTION | MATERIAL | WALL THICKNESS (cm) | CLEAVE STRENGTH (cm.kg$^{-1}$) (s.d.) |
|---|---|---|---|
| Sill | PVC (100%) | 0.38 | 1021 (38) |
| Sill | 60% PVC<br>40% sawdust | 0.38 | 382 (9) |
| Typical hollow PVC sash | PVC | 0.2 | 365 (85) |
| Modified sill | 60% PVC<br>40% sawdust | 0.38 | 328 (47) |
| PERMASHIELD casement sash | PVC clad wood | 0.12 | 168 (33) |

The data that is set forth above shows that the composite sill manufactured from the polyvinyl chloride

and the wood fibre composite material has a compression load cross grained screw retention and longitudinal screw retention superior to that of typical pine used in window manufacture. Further, the thermal transmittance of the composite material in a sill format appears to be approximately equal to that of pine even though there is about a 2° cooler interior surface temperature maintained when the interior/exterior temperature differential is about 32°C (90°F). Such thermal performance is approximately equal to that of pine but substantially better than that of aluminum.

A 90° mitred joint manufactured using the melt weld fused process set forth above, was manufactured using the composite of this invention using 60% polyvinyl chloride and 40% sawdust. The composites were compared with polyvinyl chloride, neat extrudate and polyvinyl chloride clad wood casement sash. Both low modulus (350,000 psi (2400 MPa)) and high modulus (950,000 psi (6500 MPa)) composite had a joint strength substantially greater than that of commonly available polyvinyl chloride clad wood members using commercially available casement sash. The strength was approximately equal to that of typical hollow PVC sash but was not as good as a sill manufactured from a 100% polyvinyl chloride. This data shows that the composite material of the invention can form a weld joint with a strength substantially greater than that of commercially available window member materials.

Features of polymer/wood composite materials, and components and members made from such materials, are disclosed in US patent applications numbers 07/938604, 07/938364 and 07/938365, and the European patent applications which claim priority from those applications which are being filed with this application. Reference is to be made to the specifications of those applications for information regarding those features.

## Claims

1. A structural member comprising a polymer and wood fibre composite suitable for the use as a structural member in the manufacture of a window or a door, which structural member comprises a hollow profile having a defined support direction and the compressive strength of the member in the support direction is greater than about 1500 psi (10.3 MPa) and the composite comprises a blend of wood fibre and a polymer comprising vinyl chloride in which the wood fibre is dispersed in a continuous phase, in which the amount of wood fibre is at least about 30% and the amount of the polymer is at least about 30%, the amounts being expressed by weight as a proportion of the total weight of the wood fibre and the polymer.

2. A structural member as claimed in claim 1, in which there is at least one support web, preferably two support webs.

3. A structural member as claimed in claim 1 or claim 2, in which there is at least one fastener anchor web, preferably two fastener anchor webs.

4. A structural member as claimed in any one of claims 1 to 3, which has a modulus of at least about 500,000 psi (3440 MPa).

5. A structural member as claimed in any one of claims 1 to 4, in which the compressive strength is greater than about 2000 psi (13.8 MPa)

6. A composite member as claimed in any one of claims 1 to 5, in which the amount of the polymer in the blend is more than about 35%, preferably more than about 50%.

7. A composite member as claimed in any one of claims 1 to 6, in which the blend comprises about 35 to about 65% of the polymer and about 35 to about 55% of wood fibre.

8. A composite member as claimed in any one of claims 1 to 6, in which the blend comprises about 50 to about 70% of the polymer and about 30 to about 50% of wood fibre.

9. A structural member as claimed in any one of claims 1 to 8, which is selected from the group consisting of a sill, a jamb, a stile or a rail.

10. A structural m mber as claimed in any one of claims 1 to 9, which is f rmed by extrusion or injection moulding.

11. A structural member as claimed in any one of claims 1 to 9, which has a rough opening mounting fac ,

and a shaped face adapted for a mov able window or door component.

12. A structural unit comprising at least two structural members as claimed in any one of claims 1 to 11, fixed together at a secure joint.

13. A structural unit as claimed in claim 12, in which the joint is formed by thermal welding.

14. A structural unit as claimed in claim 13, in which the joint is formed by means of a single unit inserted into each of the members.

FIG. 1

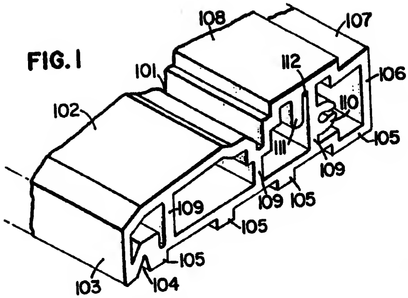



FIG. 3

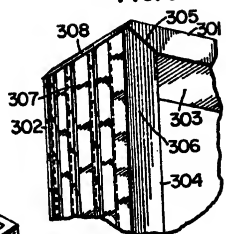



FIG. 2

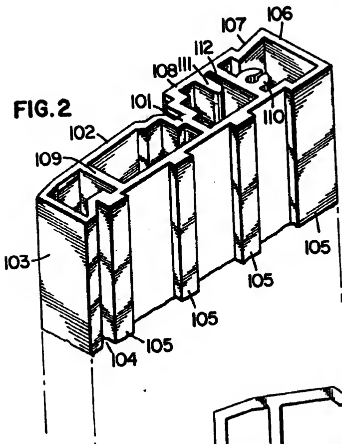
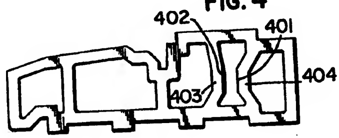



FIG. 4



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# EUROPEAN SEARCH REPORT

Application Number
EP 93 30 6845

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|---|---|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.5) |
| X | WO-A-90 08020 (POLYWOOD PATENT AB)<br>* page 4, line 26 - line 29 *<br>* page 5, line 3 - line 6 *<br>* claims 1-7,9,10 *<br>--- | 1,6-10 | B29B7/92<br>B27N3/28<br>E04C3/28<br>//B29K27:06,<br>B29K105:12 |
| Y<br><br>A | US-A-4 056 591 (L. A. GOETTLER ET AL.)<br><br><br>* column 1, line 9 - line 14 *<br>* column 3, line 43 - line 50 *<br>* column 3, line 56 - column 4, line 2 *<br>* column 4, line 15 - line 16 *<br>* column 10, line 22 - line 54 *<br>* column 11; table 1 *<br>--- | 1-3,<br>6-10,12<br>4,5 | |
| Y | US-A-3 349 538 (A. V. CROSSMAN)<br><br>* column 2, line 36 - line 55; figure 5 *<br>--- | 1-3,<br>6-10,12 | |
| A | GB-A-2 171 953 (H. MOLLER)<br>* the whole document *<br>--- | 1,2,9,10 | TECHNICAL FIELDS SEARCHED (Int.Cl.5) |
| A | US-A-4 102 106 (M. D. GOLDER ET AL.)<br><br>* column 2, line 4 - line 33; figures 1,2 *<br>--- | 1,3,9,<br>10,12 | E04C<br>B27N<br>B29B |
| A | GB-A-2 186 655 (H. MÖLLER)<br>* the whole document *<br>--- | 1,9,10 | |
| A | EP-A-0 062 533 (MONSANTO COMP.)<br>* page 10, line 24 - line 30 *<br>* page 13, line 24 - line 29 *<br>--- | 1,5,10 | |
| A | FR-A-2 564 374 (GREPP)<br>* the whole document *<br>---<br>-/-- | 1,6-10 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 19 November 1993 | FREGOSI, A |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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|---|---|---|---|
| A | US-A-4 594 372 (M. A. NATOV ET AL.)<br>* the whole document *<br>--- | 1,5-10 | |
| A | GB-A-2 104 903 (MÜANYAGIPARI KUTATO' INTEZET)<br>* the whole document *<br>----- | 1,6-8,10 | |
| | | | TECHNICAL FIELDS SEARCHED (Int.Cl.5) |

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